THE UVEAL TRACT

AUTHORS

Roger Anderson: University of Ulster

Erica Fletcher: University of Melbourne

PEER REVIEWER

Thomas Freddo: University of Waterloo

CHAPTER CONTENTS

INTRODUCTION

The Uveal Tract (latin, “uva” meaning grape) is the highly vascularised, pigmented layer of the eyeball and comprises the *iris*, *ciliary body* and *choroid*. It functions are many and varied but are, like many ocular features, given away by its structure. They therefore include: the delivery of blood supply to structures within the eye, formation of aqueous humour, accommodation, control of the amount of light entering the eye and its depth of focus.

THE IRIS

The iris is a thin circular structure located anterior to the lens. It divides the eyeball into the anterior and posterior chambers. It functions in an analogous fashion to a diaphragm of a camera or optical system. The central aperture, called the pupil, varies in diameter from approximately 1 to 9mm depending on the level of light; in high light levels, the pupil is constricted (miosis) and in low light levels the pupil dilates (mydriasis). The pupil is also the main route for flow of aqueous humour from the ciliary body to the anterior chamber.

The structure of the iris when viewed from the front can be divided into two zones. The central pupillary zone occupies the region immediately adjacent to the pupil. The edge of the pupillary zone is the thickest part of the iris, called the collarette, which is located about 1.5mm from the pupil margin (see Figure 4.1). The pupillary margin forms the border of the pupil. The ciliary zone is the part of the iris from the collarette to the iris root. Craters, referred to as *Fuch's crypts*, can be seen on the anterior surface, most commonly in the pupillary zone or around the collarette. Smaller pits can be observed near the iris root. The *Iris Ruff* can be observed at the pupillary margin and is a continuation of the posterior pigmented epithelium anteriorly through the pupil.

Colour - Iris colour is determined by the stromal *melanocytes*. Less pigment can be observed in the 'blue' coloured iris, which selectively back-scatters the shorter wavelengths of light, leading to the blue appearance. Brown is the dominant inherited colour, blue being recessive. The small number of melanocytes in the caucasian newborn gives the iris a blue appearance. Segmental variations in colour are obvious in some individuals and the colour may even differ between the eyes (*heterochromia irides*)

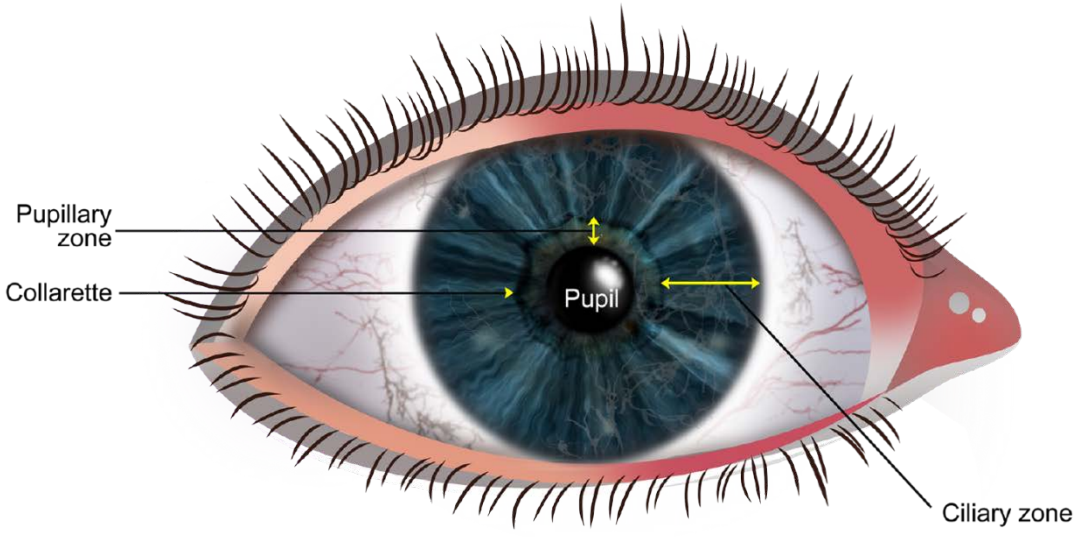

Figure 4.1: *Anterior iris surface (image adapted from http://en.wikipedia.org/wiki/File:Human_Iris_JD052007.jpg)*

Histological structure

The iris can be divided into four layers, (i) the anterior border, (ii) stroma and sphincter muscle, (iii) anterior epithelium and dilator muscle and finally (iv) the posterior epithelium.

The *Anterior Border Layer* is a condensation of the underlying stroma, It is composed of collagen fibres, melanocytes and fibroblasts and is usually non-continuous over the whole iris surface in that it does not cover the crypts. Accumulations of melanocytes appear as iris freckles.

The *Stroma* (Figure 4.2) is derived from mesenchyme and has a trabecular appearance. It is visible on the anterior surface and is composed of a loose matrix of collagen fibres with fibroblasts and melanocytes. It is highly vascular with radially running vessels that readily deform on pupil dilation. The iris arteries are branches of a circular vessel, called the major circle of the iris, which is located in the ciliary body near the iris root.

The stroma also contains the *sphincter muscle* close to the posterior surface in the pupillary zone (Figure 4.2). The sphincter pupillae is composed of smooth muscle cells. As the name implies, it is a circular muscle that encircles the pupil. It is innervated by parasympathetic nerves, and on contraction will constrict the pupil (miosis).

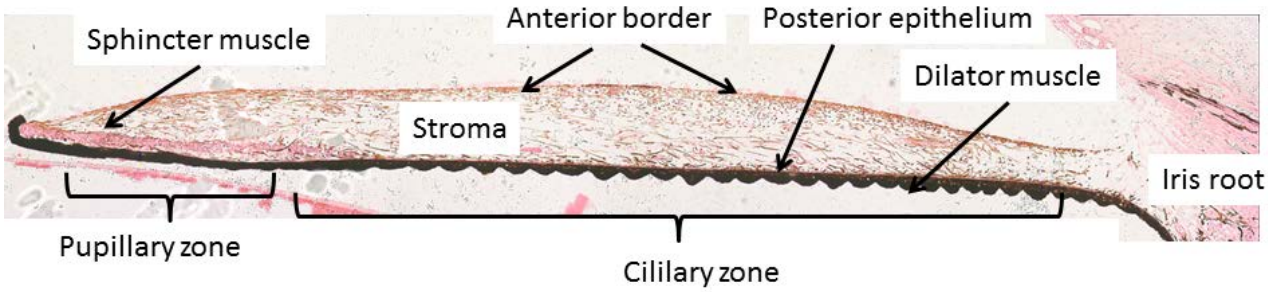

Figure 4.2: *Cross section of iris*

On the posterior aspect of the stroma are located two layers of epithelium. The first of these is called the anterior iris epithelium. This epithelial layer is composed of highly specialized myoepithelial cells. The apical side of these specialized cells consists of pigmented cuboidal epithelial cells that are joined to one another by tight junctions. The basal part of these cells, however, contains elongated contractile smooth muscle processes. These cells form the "dilator muscle" which extends from the iris root to about the mid-point of the sphincter muscle in the pupillary zone. Figure 4.3, shows a high magnification view of the iris showing the thin pink bands of the dilator muscle, and thick smooth muscle of the sphincter muscle. The second layer of epithelial cells on the posterior surface of the iris is the posterior iris epithelium. It contains large cells and that have a high melanin concentration. The iris ruff is formed by the posterior epithelium curling around the pupil margin (figure 4.3).

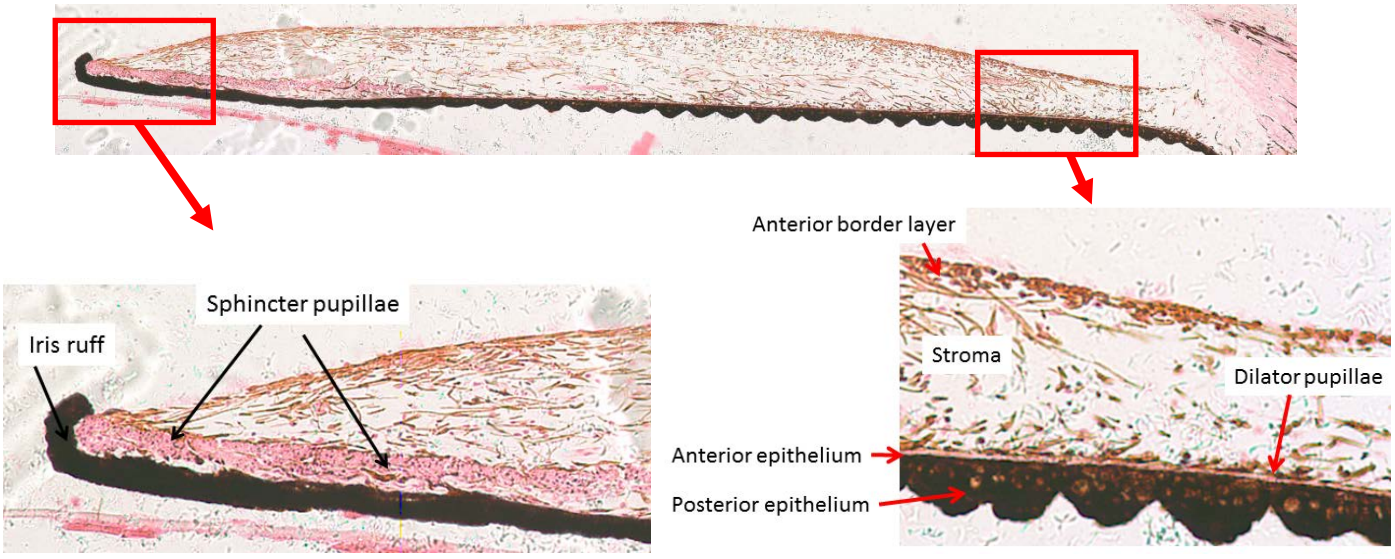

Figure 4.3: *Cross sections of the iris at the pupillary zone and the ciliary zone. Note that the iris ruff is formed by the posterior epithelium passing forward onto the pupil margin. The smooth muscle fibres of the sphincter pupillae muscle are labelled in this tissue in pink. The dilator pupillae muscle can be seen as fine strand running from the peripheral iris to more central regions. Adjacent to it, the heavily pigmented posterior epithelium can be seen.*

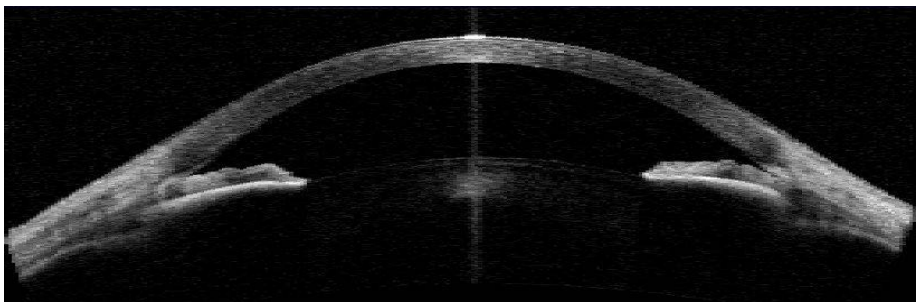

Figure 4.4 *OCT image of anterior segment showing dilated pupil. Note dense posterior epithelium of iris.*

CILIARY BODY

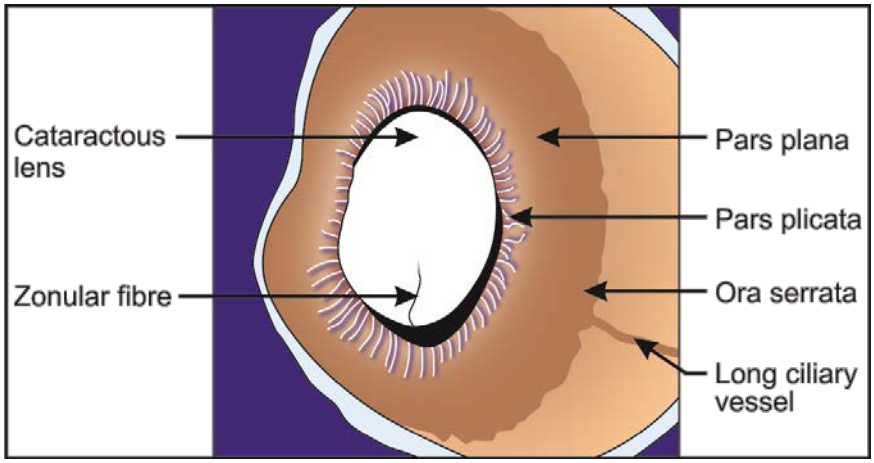

Figure 4.5: *The ciliary body viewed from inside the eye*

The ciliary body is located between the iris and choroid, and forms an annular ring approximately 6mm wide. It serves very important functions in aqueous humour production, tethering of the lens to the inside wall of the eyeball and accommodation. It extends from the *scleral spur* anteriorly to the *ora serrata* (junction with the retina) posteriorly. In cross section, the ciliary body appears triangular shaped, with one corner of the base lying adjacent to the scleral spur. The outer border of the ciliary body runs parallel with the sclera area, whilst the inner border faces the posterior chamber. The ciliary body is divided into two sections: the pars plicata contains the small finger like projections called ciliary processes. The pars plana is a flatter region that extends to the ora serrata. *Zonules* extend from between the ciliary processes and lens to tether the lens to the inside of the eyeball wall. Posteriorly, the smoother *pars plana* runs up to ora serrata.

Histological Structure

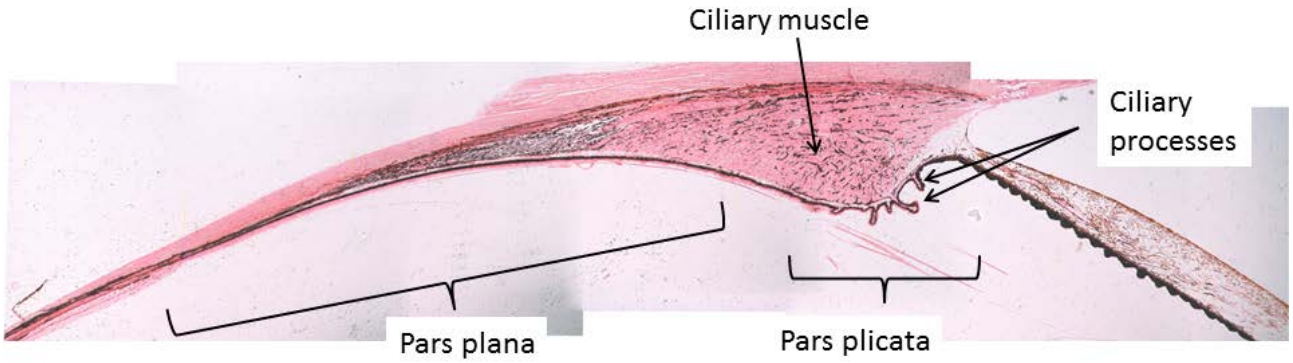

Figure 4.6: *The ciliary body in cross section.*

The most outer region of the ciliary body, adjacent to the sclera, is the **supraciliaris**, a region containing loose connective tissue that is arranged in ribbon like layers. This arrangement is thought to be important for allowing the cilary body to slide across the sclera as it contracts, without deforming the tissue.

The **ciliary stroma** forms the bulk of the ciliary body and contains the ciliary muscle. The stroma contains loose connective tissue. It is continuous anteriorly with the iris stroma, and thins within the pars plana to eventually become continuous with the choroidal stroma. The Major arterial circle of the iris is located within the ciliary stroma, anterior to the ciliary muscle and near the iris root. This arterial circle is the anastomosis of the long posterior ciliary arteries and the anterior ciliary arteries.

The **ciliary muscle** consists of smooth muscle fibres orientated in a longitudinal, radial and circular manner. The longitudinal fibres run parallel with the supraciliaris and sclera. These longitudinal fibres extend from the scleral spur to the choroid. The radial fibres are a transition zone between the longitudinal fibres and circular fibres. The inner most series of muscle fibres are the circular fibres. The circular fibres are a sphincter muscle and run circumferentially around the eyeball. The ciliary muscle is innervated by parasympathetic nerves arising from the short ciliary nerves. There may also be some sympathetic stimulation, although this is controversial

The **ciliary epithelium** is located on the most inner aspect of the ciliary body facing the posterior chamber. It consists of two layers of epithelial cells.A key feature of the epithelial cells in these two layers is that they are arranged such that their apical surfaces meet one another. This feature has significance for aqueous humour production.

The outer layer of epithelial cells (the one adjacent to the ciliary stroma) is pigmented and cuboidal. Neighbouring cells are joined to one another by desmosomes and tight junctions. The pigmented ciliary epithelium is continuous with the retinal pigment epithelium (RPE) posteriorly and anterior iris epithelium anteriorly. The pigmented epithelium sits on a basement membrane that facilitates attachment to the underlying stroma. This basement membrane is continuous with Bruch's membrane.

The inner ciliary epithelium lines the posterior chamber and is non-pigmented. It is continuous anteriorly with the posterior iris and posteriorly this structure transforms into the neural retina. In the pars plicata, these cells are cuboidal in shape, whilst in the pars plana they are columnar. Neighbouring cells have many interdigitations and are joined at their apices by desmosomes, gap junctions and zonulae occludens. These junctions provide one part of the blood-aqueous barrier. The tight junctions in the apical region of the non-pigmented epithelium form a barrier for diffusion of solutes from the tissues and vessels within the ciliary stroma. The basement membrane of the non-pigmented ciliary epithelium faces the posterior chamber. It is continuous with the inner limiting membrane of the retina, and is the site of attachment of the zonules as well as fibres of the vitreous base.

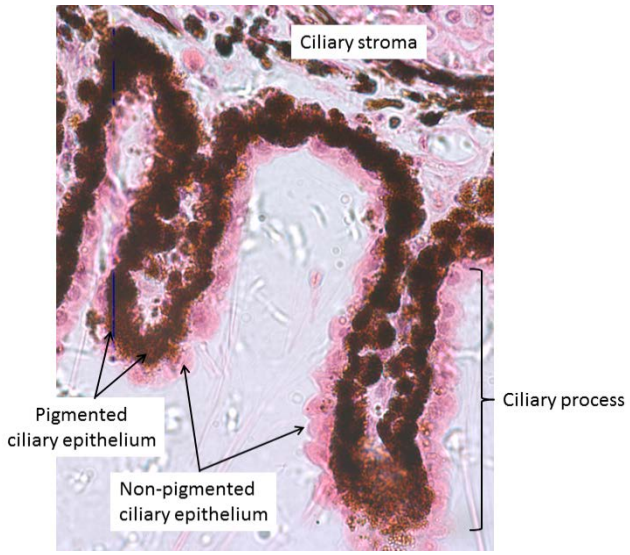

Figure 4.7: *Cross section of a ciliary process showing the two layers of ciliary epithelial cells. The inner non-pigmented epithelium and the pigmented ciliary epithelium*

Functions of the ciliary body: Aqueous Humour Production

The aqueous provides nourishment to the cornea and lens. It contains glucose, amino acids, ascorbic acid and other dissolved gases and is formed at a rate of ~2ul/min (i.e. there is a total aqueous volume change over ~100min). It is formed by the ciliary epithelium lining the ciliary processes. The process of aqueous humor formation involves three physiological processes: diffusion, ultrafiltration and active secretion. Diffusion and ultrafiltration are responsible for the accumulation of plasma ultrafiltrate within the stroma, behind the tight junctional barrier of the non-pigmented epithelium. Active secretion by the non-pigmented ciliary epithelium is thought to be the main mechanism by which aqueous humour forms.

The plasma ultrafiltrate that accumulates within the ciliary stroma passes across to the pigmented ciliary epithelium by a range of transporters and then to the non-pigmented epithelial cells via gap junctions. Finally, metabolically demanding pumps that are present on the non-pigmented epithelial surface actively pump ions into the posterior chamber. Water follows. The principal pump involved in the active transport of ions is Na+K+ATPase, which produces three sodium ions for two potassium ions into the cell. Bicarbonate ions are also transported out of the non-pigmented epithelial cells. Thus, bicarbonate ion formation by carbonic anhydrase is a key enzyme in the formation of aqueous humour.

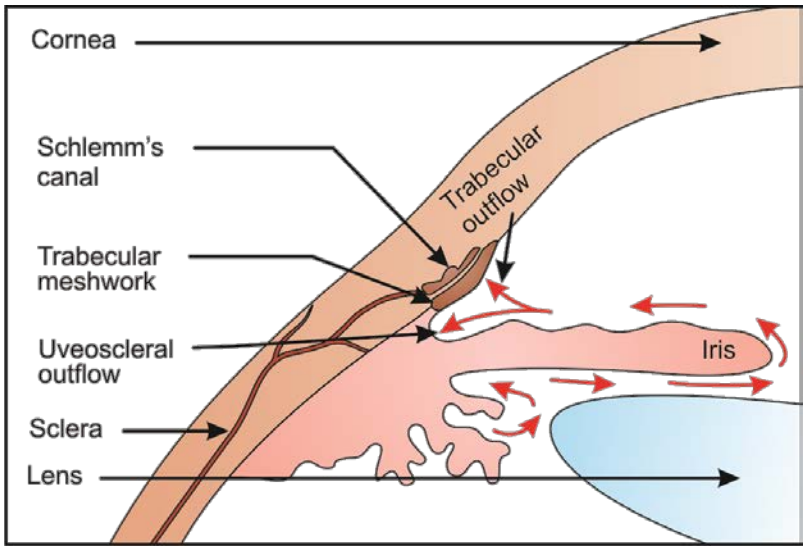

***Figure 4.8**: Circulation of aqueous humour*

Aqueous flows from the posterior chamber, through the pupil and into the *angle* between the cornea and iris (Figure 4.8). Approxiamtely 80% of outflow is via the *trabecular meshwork*, *Canal of Schlemm*, *collector channels* and *aqueous veins* (~20% via the anterior surface of the ciliary body, diffusing into the subarachnoid space). Normal intraocular pressure (IOP) is determined as a balance between production and drainage of aqueous. Flow rate is higher in waking hours and IOP peaks around mid-day. Although raised IOP is associated with many forms of glaucoma, there is no evidence that aqueous production is increased in glaucoma.

Accommodation

A second function of the ciliary body is accommodation. Current understanding of the underlying processes involved in accommodation is largely in accord with the description provided by Helmholtz in 1855. In general, when a young person is focussed on an object in the distance, the ciliary muscle is relaxed. The zonules that attach to the equator of the lens are placed under a resting tension, causing an outwardly directly force on the lens, causing flattening of the lens. When a young person looks at a close object, the ciliary muscle contracts, causing the inner apex of the ciliary body to move forward and towards the axis of the eye. This inner movement of the ciliary muscle relieves tension of the zonules, causing the lens to increase in curvature.

CHOROID

The *choroid* is a vascular layer that lies between the retina and sclera. The vessels of the choroid are the main vascular supply to outer retina (the inner retina is supplied by the retinal vessels). It is a richly vascularized and pigmented connective tissue extending from the optic nerve to the *ora serrata*.

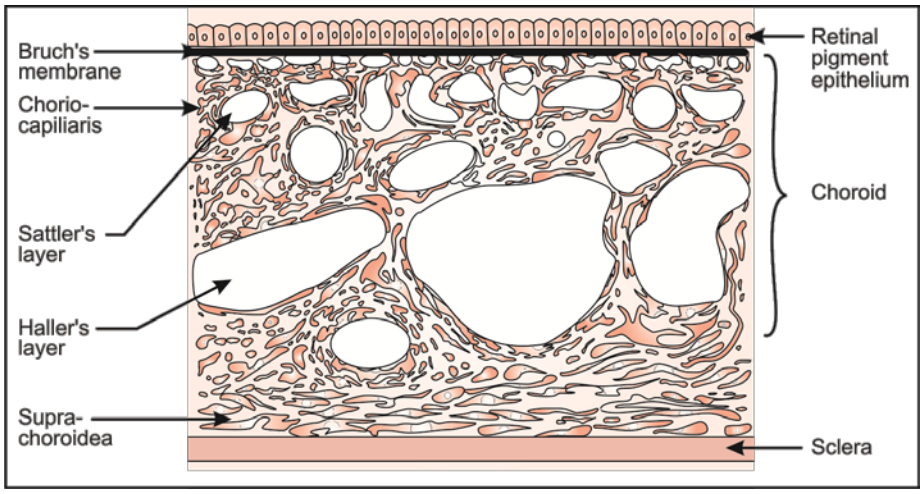

Figure 4.9: *Cross section of choroid with retinal pigment epithelium above*

It is thicker around the posterior pole than anteriorly and is especially thick at the macula. Attachment is firmest at the margin of the optic nerve and the posterior pole generally. It contains 4 main layers.

1 Externally, the *lamina fusca (or suprachoroid)* lies adjacent to the sclera, is 10-30 microns thick and composed of flattened laminae made up of collagen fibres, melanocytes and fibroblasts. The laminae are more adherent to each other posteriorly (choroidal detachment is thus more common anteriorly).

2. The *stroma* is composed of loose collagenous tissue with some elastic fibres and contains many blood vessels. Especially noticeable are the *melanocytes*. Unlike most connective tissues where vessels of varying calibre are found throughout the tissue, vessels of different sizes are present in progressive layers, with the largest vessels closest to the sclera and the smallest calibre adjacent to Bruchs membrane and the retinal pigmented epithelium. The layer of large vessels closest to the sclera is known as *Haller's layer*, and a medium sized vessel layer, known as *Sattler's layer* separates *Haller's layer* from the layer of choroidal capillaries termed the *choriocapillaris.*

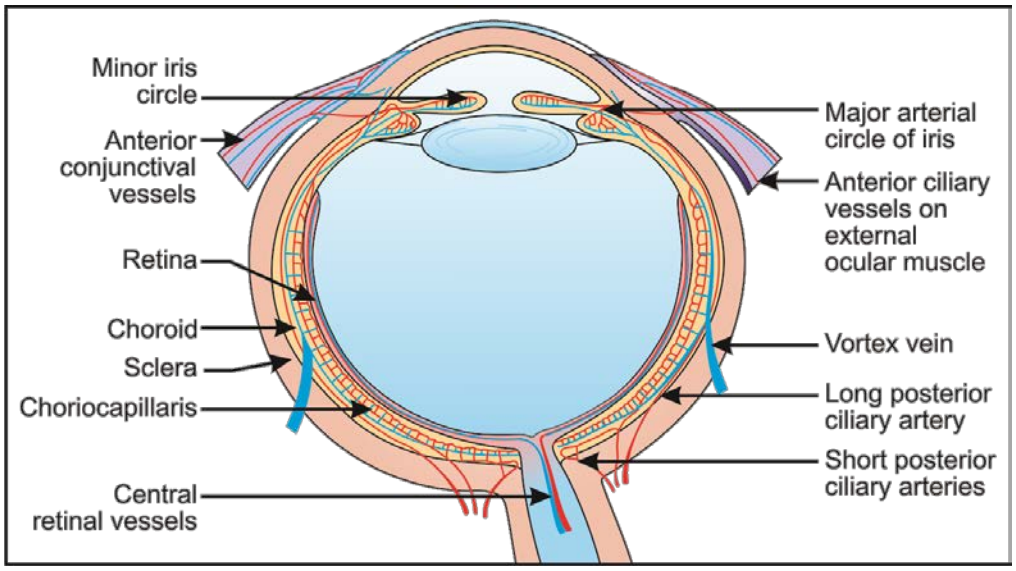

Figure 4.10: *Blood supply to the uvea*

The large vessels derive from two sources:

i. Divisions of the short posterior ciliary arteries, which pierce the sclera and enter choroid around optic nerve. These vessels divide and run through the choroid as far as the equator.

ii. Recurrent vessels from the *anterior ciliary arteries* and *major arterial circle* of the iris anteriorly head backwards, dividing as they go, to meet up with the other vessels at the equator.

3. The *choriocapillaris* (nearest the retina) consists of wide bore capillaries and provides nourishment to the outer retina. Little or no pigment is observed in the choriocapillaris layer. The capillaries are densest and with the largest bore at the macula.

4. *The basal lamina,* known as *Bruch's membrane*, is a compound basement membrane between the pigment epithelium of the retina and the endothelium of the choriocapillaris. Around 2 microns thick in the young adult, it increases in thickness with age. Separate collagenous and elastic layers can be observed on closer inspection. Bruch's membrane is smooth and regular in the central region.